

**COMPARISON OF OCEANIC  $\Delta^{14}\text{C}$  DATA WITH THOSE OF  
GEOSECS: VERTICAL PROFILES IN 1973 (GEOSECS)  
AND IN 1980 AT (30° N, 170° E) IN THE NORTHWESTERN  
PACIFIC OCEAN**

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**ABSTRACT.** The vertical profile of radiocarbon at (30° N, 170° E) measured in 1980 was compared with the GEOSECS data measured in 1973.  $^{14}\text{C}$  was extracted from 200L of sea water, converted to  $\text{C}_2\text{H}_2$ , and analyzed with a gas proportional counter. Our profile and that of GEOSECS were in good agreement below 700m depth without systematic deviation of  $\Delta^{14}\text{C}$  values between both measurements. On the other hand, a  $\Delta^{14}\text{C}$  increase was observed above 700m depth, reflecting the transient addition, in 6.6 years, of bomb  $^{14}\text{C}$  to the intermediate layer from the atmosphere.

INTRODUCTION

It is well known that  $^{14}\text{C}$  is one of the most important geochemical tracers for studying ocean circulation and mixing processes (eg, Broecker & Peng, 1982). The  $^{14}\text{C}$  distributions in the Pacific Ocean were obtained in detail during the GEOSECS operation in 1973–1974 (Östlund & Stuiver, 1980). We re-occupied one of the GEOSECS stations—Station 226 (30°N, 170°E)—during the CYGNUS Expedition (KH-80-2) of *R V Hakuho Maru* in 1980 (Horibe, 1983), in order to compare our  $\Delta^{14}\text{C}$  data with those of the GEOSECS group. This paper reports the method for  $\Delta^{14}\text{C}$  measurement and the result of intercomparison of the  $\Delta^{14}\text{C}$  profiles.

EXPERIMENTAL

Fifteen seawater samples from surface to bottom (as listed in Table 1) were collected by using water-tight PVC 230L water samplers (Horibe, 1981) at Station CYGNUS 11 (30° 32' N, 170° 39' E). To measure the precise depth and temperature of each sample, a sonar pinger (Benthos, Model 2216) and reversing thermometers were attached to the sampler.

As soon as the sampler was brought on deck, 200L of sea water were transferred into a stainless steel barrel to extract the dissolved total inorganic carbon ( $\Sigma\text{CO}_2$ ). The extraction method was similar to that reported by Östlund, Dorsey and Rooth (1974). The sea water was acidified with  $\text{HCl}$  and stripped of  $\Sigma\text{CO}_2$  by circulating  $\text{CO}_2$ -free nitrogen carrier gas. The extracted  $\text{CO}_2$  was absorbed in 800ml carbonate-free 4N NaOH solution which was prepared by diluting clear saturated solution of NaOH with distilled water just before its use. The flow rate of the carrier gas was

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TABLE 1  
Results of measurements at Station CYGNUS 11 (30° 32' N, 170° 39' E)  
June 6–7, 1980

Sample no.	Depth (m)	A <sub>SN</sub> (cpm)	δ <sup>13</sup> C (‰)	Δ <sup>14</sup> C (‰)
TK-376	10	15.41 ± 0.06	1.0	164 ± 5
TK-375	94	14.90 ± 0.06	0.7	126 ± 5
TK-374	221	14.75 ± 0.05	0.3	116 ± 5
TK-373	467	13.43 ± 0.06	-0.4	17 ± 5
TK-372	684	11.95 ± 0.05	-1.0	-94 ± 4
TK-371	808	10.92 ± 0.05	-1.4	-171 ± 4
TK-370	1001	10.71 ± 0.05	-1.7	-186 ± 4
TK-369	1235	10.23 ± 0.05	-1.8	-223 ± 4
TK-368	1559	10.10 ± 0.04	-1.7	-233 ± 4
TK-367	2022	10.02 ± 0.05	-1.1	-240 ± 4
TK-366	2542	10.02 ± 0.05	-0.7	-240 ± 4
TK-365	3012	10.27 ± 0.05	-0.5	-222 ± 4
TK-364	4055	10.31 ± 0.05	-0.6	-219 ± 4
TK-363	4953	10.33 ± 0.05	-0.9	-217 ± 4
TK-362	5396	10.47 ± 0.04	-1.0	-206 ± 4

adjusted to ca 6L per minute. By analyzing the remaining ΣCO<sub>2</sub> content in the sample sea water with the gas chromatograph (Gamo & Horibe, 1980) at appropriate time intervals during the extraction, it was found that 3 hours were necessary to achieve 95% extraction of ΣCO<sub>2</sub>. In this study, the extraction was continued for >4 hours for every sample.

In the laboratory on land, CO<sub>2</sub> was recovered by acidifying the NaOH solution with HCl, and converted to C<sub>2</sub>H<sub>2</sub> gas for β counting. Standard gases were prepared from the old NBS oxalic acid by using a wet oxidation method. The <sup>14</sup>C measurement was carried out with the gas proportional counter described by Kobayashi *et al* (1974).

A fraction of the C<sub>2</sub>H<sub>2</sub> gas was subjected to quantitative combustion to CO<sub>2</sub>, and its δ<sup>13</sup>C relative to PDB was measured with the Finnigan MAT 250 mass spectrometer. The Δ<sup>14</sup>C value of the sample was calculated according to the following equation:

$$\Delta^{14}\text{C} = (A_{\text{SN}}/A_{\text{ABS}} - 1) \times 1000 \text{ (‰)}$$

where A<sub>SN</sub> is the net <sup>14</sup>C activity of the sample normalized to δ<sup>13</sup>C = -25‰, and A<sub>ABS</sub> (absolute international standard activity) is 95% of the net oxalic acid activity in AD 1950 which is normalized to δ<sup>13</sup>C = -19‰ (Stuiver & Polach, 1977).

The standard deviation for each Δ<sup>14</sup>C data was calculated from statistical error of β countings. When the total count is N (counts), its standard deviation is √N. The counting rate is expressed as N/T (T: counting time) and its standard deviation is √N/T<sup>2</sup>. After the standard deviations for A<sub>SN</sub> and A<sub>ABS</sub> are obtained as σ<sub>1</sub> and σ<sub>2</sub>, respectively, that for Δ<sup>14</sup>C is calculated by the following equation.

$$\sigma = \left( \frac{1}{A_{\text{ABS}}} \sqrt{(A_{\text{ABS}} \cdot \sigma_1)^2 + (A_{\text{SN}} \cdot \sigma_2)^2} \right) \times 1000$$

TABLE 2  
Results of the NBS standard measurements

NBS no.	$A_{\text{ox}}$ (cpm)	$\delta^{13}\text{C}$ (‰)	$A_{\text{ABS}}$ (cpm)
NBS-42	$13.02 \pm 0.06$	-22.9	$12.51 \pm 0.06$
-42	$13.08 \pm 0.07$	-22.9	$12.57 \pm 0.07$
-43	$13.14 \pm 0.05$	-20.9	$12.58 \pm 0.05$

## RESULTS AND DISCUSSION

Two standard gases (NBS-42 and NBS-43) were prepared for this study. Table 2 shows the results of the standard gas measurements: their net activity ( $A_{\text{OX}}$ ),  $\delta^{13}\text{C}$ , and  $A_{\text{ABS}}$ . The standard gases were measured three times at intervals in the course of successive sample measurements. The good reproducibility of the value of  $A_{\text{ABS}}$  (average value:  $12.55 \pm 0.03$  cpm) reflected the stability of the counting system throughout the study.

The results of sample measurements and calculated  $\Delta^{14}\text{C}$  values were listed in Table 1. Figure 1 is the vertical  $\Delta^{14}\text{C}$  profile at CYGNUS Station 11 together with that at GEOSECS Station 226 (Östlund & Stuiver, 1980). The former samples were collected June 6–7, 1980, and the latter November 9, 1973. In deep waters below 700m depth, both profiles are in good agreement with each other within the analytical error as indicated by a solid line

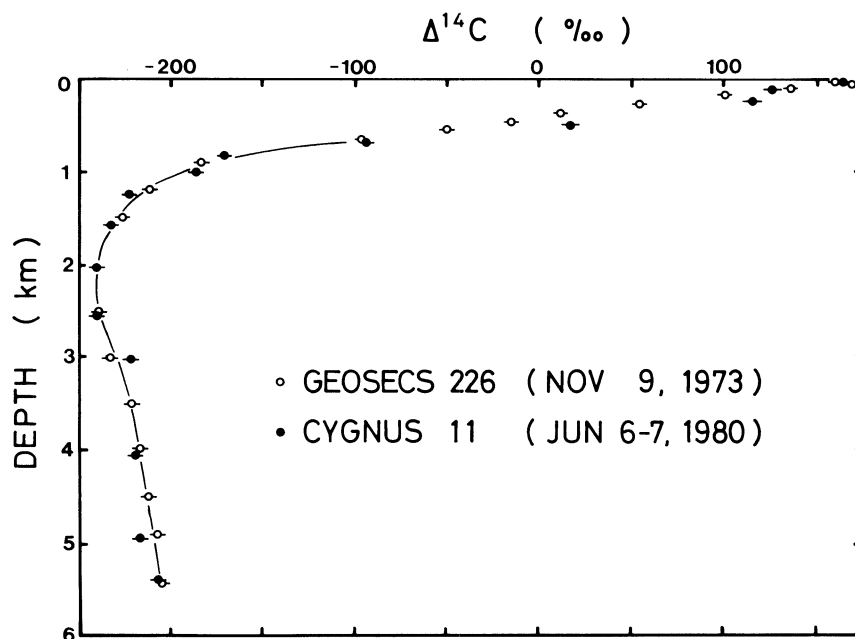


Fig 1. Comparison of the vertical profiles of  $\Delta^{14}\text{C}$  between GEOSECS 226 ( $30^{\circ} 34' \text{N}$ ,  $170^{\circ} 38' \text{E}$ ) in 1973 and CYGNUS 11 ( $30^{\circ} 32' \text{N}$ ,  $170^{\circ} 39' \text{E}$ ) in 1980. The solid line was arbitrarily drawn to show good agreement between both profiles below 700m depth.

in Figure 1. Thus, there is no systematic deviation between our  $\Delta^{14}\text{C}$  measurements and those of the GEOSECS group.

As shown in Figure 1, above 700m depth our 1980  $\Delta^{14}\text{C}$  data at 221m and 467m depths are significantly greater than the 1973 GEOSECS values interpolated at the same depths. Since it was shown above that there is no analytical bias between both measurements, the increase of  $\Delta^{14}\text{C}$  is real, possibly reflecting the addition of bomb  $^{14}\text{C}$  from the atmosphere. As the  $\Delta^{14}\text{C}$  increase was limited in the intermediate depth range and no change was observed in the surface water, it is supposed that the bomb  $^{14}\text{C}$  was supplied to the intermediate water by transport of sinking surface sea water in the northern region of the Pacific.

The similar increase of  $\Delta^{14}\text{C}$  in the intermediate layer compared with the GEOSECS data was observed also at (25° N, 170° E) (GEOSECS 227, CEPHEUS 5) and at (12° 45' N, 173° 14' E) (GEOSECS 229, CEPHEUS 8) during the CEPHEUS Expedition of *R V Hakuho Maru* in 1982 as presented by Horibe and Gamo (1983). The transient behavior of  $^{14}\text{C}$  in the intermediate layer and its oceanographic meanings will be discussed elsewhere in detail together with other results so far obtained in the northwestern Pacific Ocean.

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